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SURFACE ACOUSTIC WAVE BRANCHING FILTER

Technical Field

The present invention relates to a surface acoustic wave branching filter using first and second surface acoustic filters having different passbands and more particularly to a surface acoustic wave branching filter of a ladder-type circuit structure having pluralities of series-arm resonators and parallel-arm resonators.

Background Art

Up to now, various surface acoustic wave branching filters using a surface acoustic wave filter of a ladder-type circuit structure having series-arm resonators and parallel-arm resonators have been proposed.

For example, in the following Patent Document 1, a surface acoustic wave branching filter shown in Fig. 12 is disclosed. Here, a first surface acoustic wave filter F_1 for relatively low frequencies and a second surface acoustic wave filter F_2 for relatively high frequencies are connected to an antenna-side common terminal T_0. The surface acoustic wave filter F_1 includes a series-arm resonator R_{S0} and a parallel-arm resonator R_P, and the second surface acoustic wave filter F_2 includes a parallel-arm resonator R_{P0} and a series-arm resonator R_S.

In the first surface acoustic wave filter F_1, a resonator close to the common antenna terminal T_0 is the series-arm resonator R_{S0} and, in the second surface acoustic wave filter F_2, a resonance close to the common antenna terminal T_0 is the parallel-arm resonator R_{P0}.

Furthermore, a phase rotation line S is sandwiched between the second surface acoustic wave filter F_2 and the common antenna terminal T_0.

On the other hand, in the following Patent Document 2, a surface acoustic wave filter of a ladder-type circuit structure shown in Fig.

13 is disclosed. Here, series-arm resonators R_{S1} and R_{S2} are connected in series in a series arm between an input terminal and an output terminal. Furthermore, a parallel-arm resonator R_{P1} is disposed in a parallel arm connected between the input terminal and the series-arm resonator R_{S1}. Furthermore, a parallel-arm resonator R_{P2} is disposed in a parallel arm one end of which is connected between the series-arm resonators R_{S1} and R_{S2}. Moreover, a parallel-arm resonator R_{P3} is disposed in a parallel arm between the series-arm resonator R_{P2} and the output terminal.

In this surface acoustic wave filter, the three parallel-arm resonators R_{P1} to R_{P3} are commonly connected to a common terminal 51 on a surface acoustic wave chip. Then, the common terminal 51 and the ground terminal of a package are connected by a bonding wire having an inductance L_E.

On the other hand, in the following Patent Document 3, it is described that, in a surface acoustic wave filter of a ladder-type circuit structure, the best capacitance ratio between a parallel-arm resonator disposed at an end portion and a parallel-arm resonator connected in a parallel arm sandwiched between series-arm resonators is 1/2.

Moreover, in the following Patent Document 4, a surface acoustic wave branching filter shown in Fig. 14 is disclosed. As shown in Fig. 14, in a surface acoustic wave branching filter 70, a first surface acoustic wave filter 61 for relatively low frequencies and a second surface acoustic wave filter 62 for relatively high frequencies are connected to a common terminal 71 on the antenna side. The surface acoustic wave filters 61 and 62 are surface acoustic wave filters of a ladder-type circuit structure having series-arm resonators S1 to S3 and parallel-arm resonators P1 to P6, respectively.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2000-315936

Patent Document 2: Japanese Unexamined Patent Application Publication No. 10-93382

Patent Document 3: Japanese Unexamined Patent Application Publication No. 5-183380

Patent Document 4: Japanese Unexamined Patent Application Publication No. 2001-298348

Disclosure of Invention

In a surface acoustic wave branching filter described in Patent Document 1, the series-arm resonator R_{S0} is connected to a first stage of the first surface acoustic wave filter F_1 for relatively low frequencies, and the above-described phase rotation line S is connected to the second surface acoustic wave filter F_2.

In recent years, the reduction in size has also been strongly required in surface acoustic wave branching filters. Accordingly, when the phase rotation line S is constituted in a package, it has been difficult to ensure a sufficient line length for fully rotating the phase. Furthermore, the longer the line length of the phase rotation line S, the larger the resistance of the line. Accordingly, there has been a problem in that the loss of the surface acoustic wave branching filters increases.

On the other hand, when the line length of the phase rotation line S is reduced, the amount of phase rotation becomes small, the impedance matching of the surface acoustic wave filter F_2 deviates from a reference impedance of 50 Ω, the loss in the band increases, and there was a fear that isolation characteristics might deteriorate.

In the surface acoustic wave filter described in the above-described Patent Document 2, it is stated that the amount of attenuation can be improved by commonly connecting the ground-side terminals of the parallel-arm resonators R_{P1} to R_{P3}. However, in Patent Document 2, only a technique for improving the amount of attenuation of a surface acoustic wave filter is disclosed and, in Patent Document

2, nothing about the concrete structure of series-arm resonators and parallel-arm resonators in a surface acoustic wave branching filter is described.

Furthermore, in Patent Document 3, in the surface acoustic wave filter of a ladder-type circuit structure, although the capacitance ratio between a parallel-arm resonator disposed at an end portion and a parallel-arm resonator in a parallel arm disposed between series-arm resonators is described, it is only described to make the capacitance ratio of the parallel-arm resonators a fixed value. That is, nothing is described concerning a desirable structure of the series-arm resonators and the parallel-arm resonators in surface acoustic wave branching filters using a plurality of surface acoustic wave filters.

In the surface acoustic wave branching filter described in the above Patent Document 4, the surface acoustic wave branching filter 70 using the surface acoustic wave filters 61 and 62 in which a resonator closest to the common terminal 71 is the parallel-arm resonator S_1. However, in the surface acoustic wave branching filter 70, a desirable structure of each of the series-arm resonators S1 to S3 and parallel-arm resonators P1 to P6, phase delay circuits, etc., are not particularly mentioned.

It is an object of the present invention to provide a structure being able to be reduced in size without having isolation characteristics deteriorated and having the loss increased in a surface acoustic wave branching filter in which a first surface acoustic wave filter having a relatively low passband and a second surface acoustic wave filter having a relatively high passband are connected to a common terminal on the antenna side and each surface acoustic wave filter is composed of a ladder-type surface acoustic wave filter.

In the present invention, a surface acoustic wave branching filter includes a first surface acoustic wave filter having a relatively low

passband; a second surface acoustic wave filter having a relatively high passband; and a first common terminal to which one ends of the first and second surface acoustic wave filters are connected and which is connected to an antenna. In the surface acoustic wave branching filter, the first surface acoustic wave filter is a surface acoustic wave filter of a ladder-type circuit structure having a plurality of parallel-arm resonators and a plurality of series-arm resonators.

Out of the pluralities of series-arm resonators and parallel-arm resonators, a resonator being the closest to the first common terminal is a parallel-arm resonator and the capacitance of the parallel-arm resonator being the closest to the first common terminal is less than 1/2 of the capacitance of a parallel-arm resonator, different from the parallel-arm resonator, sandwiched between series-arm resonators.

In a particular aspect of a surface acoustic wave branching filter of the present invention, the capacitance of the parallel-arm resonator being the closest to the first common terminal is in the range of 1/40 to 1/5 of the capacitance of the other parallel-arm resonator sandwiched between different series-arm resonators.

In another particular aspect of a surface acoustic wave branching filter of the present invention, the surface acoustic wave branching filter further includes a second common terminal to which one end of a parallel-arm resonator being the closest to the first common terminal and one end of the other parallel-arm resonator are connected, and an inductance element added between the second common terminal and the ground potential.

In another particular aspect of a surface acoustic wave branching filter of the present invention, the surface acoustic wave branching filter further includes a package material housing the first and second surface acoustic wave filters, wherein the second common terminal is included in the package material.

In another particular aspect of a surface acoustic wave branching

filter of the present invention, the resonance frequency of the parallel-arm resonator being the closest to the first common terminal is substantially the same as the resonance frequency of the other parallel-arm resonator.

In another particular aspect of a surface acoustic wave branching filter of the present invention, the surface acoustic wave branching filter further comprises a phase adjustment element inserted between the second surface acoustic wave filter and the first common terminal.

In another particular aspect of a surface acoustic wave branching filter of the present invention, the amount of phase delay of the phase adjustment element is less than 90 degrees from the central frequency of the first surface acoustic wave filter and, when seen from the side of the first common terminal, at least 50% of the passband of the second surface acoustic wave filter is inductive.

In another particular aspect of a surface acoustic wave branching filter of the present invention, the phase adjustment element is a stripline.

In another particular aspect of a surface acoustic wave branching filter of the present invention, the phase adjustment element includes a capacitance element and a second inductance element.

In another particular aspect of a surface acoustic wave branching filter of the present invention, when seen from the first common terminal, at least 50% of the passband of the second surface acoustic wave filter is inductive.

In a surface acoustic wave branching filter of the present invention, one ends of a first surface acoustic wave filter having a relatively low passband and a second surface acoustic wave filter having a relatively high passband are connected to a first common terminal connected to an antenna side; in the surface acoustic wave branching filter in which the first surface acoustic wave filter is composed of a surface acoustic wave filter of a ladder-type circuit

structure, out of pluralities of series-arm resonators and parallel-arm resonators of the first surface acoustic wave filter, a resonator being the closest to the first common terminal is a parallel-arm resonator; and the capacitance of the parallel-arm resonator being the closest to the first common terminal is less than 1/2 of the capacitance of the other parallel-arm resonator sandwiched between series-arm resonators different from the parallel-arm resonator. Therefore, while deterioration of the of the insertion loss is suppressed, isolation characteristics can be improved. In particular, when the above capacitance ratio is in the range of 1/40 to 1/5, deterioration of the insertion loss is more suppressed and simultaneously isolation characteristics can be effectively improved.

One end of the parallel-arm resonator being the closest to the first common terminal and one end of the other parallel-arm resonator are connected to a second common terminal, and, when an inductance element is connected between the second common terminal and the ground potential, even if the capacitance of the parallel-arm resonator is reduced, isolation characteristics can be more effectively improved.

Furthermore, when the second common terminal is included in a package, the above inductance element can be constituted in the package and the surface acoustic wave filter can be reduced in size.

When the resonance frequency of the parallel-arm resonator being the closest to the first common terminal is substantially the same as the resonance frequency of the other parallel-arm resonator, isolation characteristics can be effectively improved without having the insertion loss due to the difference of characteristics of the parallel-arm resonators caused.

When a phase adjustment element is inserted between the second surface acoustic wave filter and the first common terminal, the loss at the first common terminal on the antenna side can be effectively reduced by the phase adjustment element.

When the amount of phase delay of the phase adjustment element is less than 90 degrees from the central frequency of the first surface acoustic wave filter and, when seen from the side of the first common terminal, at least 50% of the passband of the second surface acoustic wave filter is inductive, the DPX coupling loss at the common terminal on the antenna side can be effectively reduced.

When the phase adjustment element is composed of a stripline, the stripline can be easily formed in the package and the loss can be reduced without preventing the reduction of a surface acoustic wave branching filter in size.

When the phase adjustment element is a phase adjustment circuit having a capacitance element and a second inductance element, the DPX coupling loss at the common terminal on the antenna side can be more reduced.

When seen from the side of the first common terminal, if at least 50% of the passband of the second surface acoustic wave filter is inductive, the DPX coupling loss at the common terminal on the antenna side can be effectively reduced.

Brief Description of the Drawings

Fig. 1 shows the circuit structure of a surface acoustic wave branching filter according to one embodiment of the present invention.

Fig. 2 is a schematic top view showing the electrode structure of a surface acoustic wave resonator used as a series-arm resonator or parallel-arm resonator in the embodiment of the present invention.

Fig. 3 is a schematic sectional front view showing the physical structure of the surface acoustic wave branching filter of the embodiment of the present invention.

Fig. 4 shows the change of isolation when the capacitance ratio of the parallel-arm resonator in the surface acoustic wave branching filter of the first embodiment is changed.

Fig. 5 shows isolation characteristics when the parallel-arm

resonator being the closest to a first common terminal on the antenna side is not included and when the capacitance ratio of the parallel-arm resonator is 1/20 and 1/10.

Fig. 6 shows the relation between the capacitance ratio and the insertion loss of a parallel-arm resonator.

Fig. 7 shows frequency characteristics of the amount of attenuation when a parallel-arm resonator being the closest to a first common terminal in a surface acoustic wave filter is not included and when the capacitive ratio of a parallel-arm resonator is 1/20 and 1/10.

Fig. 8 shows the relation between the capacitance ratio of a parallel-arm resonator and the insertion loss of a transmission side surface acoustic wave filter.

Fig. 9 shows frequency characteristics of the amount of attenuation of a reception side surface acoustic wave filter when the parallel-arm resonator as a resonator being the closest to the first common terminal in a first surface acoustic wave filter is not included and when the capacitance ratio of the parallel-arm resonator is 1/20 and 1/10.

Fig. 10 shows the change of admittance on an admittance Smith chart when the phase is capacitive in the case where the resonator being the closest to the first common terminal on the antenna side is a parallel-arm resonator.

Fig. 11 shows the change of impedance on an impedance Smith chart when the series-arm resonator is capacitive in the case where the resonator being the closest to the first common terminal on the antenna side is a series-arm resonator.

Fig. 12 is a circuit diagram showing one example of related surface acoustic wave branching filers.

Fig. 13 is a circuit diagram showing one example of related surface acoustic wave branching filers.

Fig. 14 is a circuit diagram showing another example of related

surface acoustic wave branching filers.

Reference Numerals

1 surface acoustic wave branching filter

2 antenna terminal

3 low-pass filter

4 first common terminal

5 transmission side surface acoustic wave filter (first surface acoustic wave filter)

5A transmission side surface acoustic wave filter chip

6 reception side surface acoustic wave filter (second surface acoustic wave filter)

6A reception side surface acoustic wave filter chip

7 second common terminal

9 phase adjustment element

11 surface acoustic wave resonator

12 comb electrode

13 and 14 reflectors

15 case material

16 lid

17 package

18 metal bump

19, 20, and 21 via-hole electrodes

22 and 23 striplines

24 to 26 via-hole electrodes

ANT antenna

Z inductance element

Best Mode for Carrying Out the Invention

Hereinafter, the present invention is made clear by describing concrete embodiments of the present invention with reference to the drawings.

Fig. 1 shows the circuit structure of a surface acoustic wave

branching filter according to a first embodiment of the present invention.

In the surface acoustic wave branching filter of the present embodiment, the passband on the transmission side is 824 to 849 MHz and the passband on the reception side is 869 to 894 MHz.

A surface acoustic wave branching filter 1 includes an ANT terminal 2 belonging to an antenna ANT. One end of a low-pass filter 3 is connected to the ANT terminal 2 and the other end of the low-pass filter 3 is connected to a first common terminal 4. That is, the first common terminal 4 is connected to the antenna ANT through the low-pass filter 3.

A transmission side surface acoustic wave filter 5 as a first surface acoustic wave filter having a relatively low passband and a reception side surface acoustic wave filter 6 as a second surface acoustic wave filter having a relatively high passband are connected to the first common terminal 4.

Each of the transmission side surface acoustic wave filter 5 and the reception side surface acoustic wave filter 6 is a surface acoustic wave filter of a ladder-type circuit structure having a plurality of series-arm resonators and a plurality of parallel-arm resonators.

Fig. 2 is a schematic top view showing the electrode structure of one surface acoustic wave resonator used as a parallel resonator or a series resonator in the surface acoustic wave filters 5 and 6. A surface acoustic wave resonator 11 includes a comb electrode 12 and reflectors 13 and 14 disposed on both sides in the surface acoustic wave propagation direction of the comb electrode 12. Moreover, in each of the series resonators and parallel resonators, the number, pitch, etc., of electrode fingers of the comb electrodes are properly selected in accordance with its capacitance and frequency.

The transmission side surface acoustic wave filter 5 includes

series-arm resonators T2, T3, T5, T6, T8, and T9 and parallel-arm resonators T1, T4, and T7. In the transmission side surface acoustic wave filter 5, a resonator being the closest to the first common terminal 4 is the parallel-arm resonator T1. The parallel-arm resonator T4 is included in a parallel arm one end of which is connected between the series-arm resonators T3 and T5. Furthermore, the parallel-arm resonator T7 is disposed in a parallel arm one end of which is connected between the series-arm resonators T6 and T8.

The ground-side terminal of the parallel-arm resonators T1, T4, and T7 is commonly connected to a second common terminal 7 included in a package to be described later. Furthermore, an inductance element Z is connected between the second common terminal 7 and the ground potential.

On the other hand, the reception side surface acoustic wave filter 6 as the second surface acoustic wave filter includes parallel-arm resonators R1, R4, and R7 and series-arm resonators R2, R3, R5, and R6. Out of these resonators, the parallel-arm resonator R1 is the closest resonator to the first common terminal 4. The parallel-arm resonator R4 is included in a parallel arm one end of which is connected between the series-arm resonators R3 and R5, and the parallel-arm resonator R7 is disposed in a parallel arm one end of which is connected between the series-arm resonator R6 and an reception-side output terminal.

Moreover, a phase adjustment element 9 is disposed between the reception side surface acoustic wave filter 6 and the first common terminal 4.

Fig. 3 is a schematic sectional front view showing the physical structure of the surface acoustic wave branching filter of the present embodiment. The surface acoustic wave branching filter 1 includes a package 17 made up of a case material 15 and a lid 16. The case material 15 is composed of insulating ceramics such as aluminum, etc., or an insulating material such as synthetic resin, etc. The lid 16 is

composed of an appropriate material such as a conductive material of metal, etc., or an insulating material such as alumina, etc.

The case material 15 includes a concave portion 15a which is open upward, and a transmission side surface acoustic wave filter chip 5A constituting the transmission side surface acoustic wave filter and a reception side surface acoustic wave filter chip 6A constituting the reception side surface acoustic wave filter 6 are housed in the concave portion 15a. The surface acoustic wave filter chips 5A and 6A are mounted on the case material 15 by a flip-chip bonding method. Fig. 3 shows the surface acoustic wave filter chips 5A and 6A joined to the bottom surface of the concave portion 15a by metal bumps 18 schematically shown. In practice, the electrodes of the surface acoustic wave filter chips 5A and 6A are electrically connected to the electrode lands formed on the bottom surface of the concave portion 15 of the case material 15 by the metal bumps 18.

Furthermore, via-hole electrodes 19 and 20 are formed in the case material 15. A phase adjustment element 9 composed of striplines 22 and 23 connected by a via-hole electrode 21 is constituted between the via-hole electrodes 19 and 20.

On the other hand, via-holes 24 and 25 are disposed under the transmission side surface acoustic wave filter chip 5A in the case material 15. The upper end of the via-hole electrodes 24 and 25 reach the bottom surface of the concave portion 15a of the case material 15, and the upper end is connected to the parallel-arm resonators T4 and T1 shown in Fig. 1. The lower end of the via-hole electrodes 24 and 25 is connected to the second common terminal 7. The via-hole electrode (not shown in Fig. 3) connected to the ground-side terminal of the parallel-arm resonator T7 shown in Fig. 1 is also connected to the second common terminal 7.

The second common terminal 7 is embedded in the case material 15, and the upper end of a via-hole electrode 26 is connected to the lower

surface of the second common terminal 7. The lower end of the via-hole electrode 26 reaches the lower surface of the case material 15 and is connected to a ground electrode (not illustrated) formed on the lower surface of the case material 15.

In the present embodiment, the surface acoustic wave filter chips 5A and 6A are constituted in such a way that a surface acoustic wave resonator and electrodes constituting connection electrodes are formed on a $LiTaO_3$ substrate by using an electrode material having aluminum as a main component.

Furthermore, the above phase adjustment striplines 22 and 23 have a characteristic impedance of about 50 Ω, and the amount of phase shift is set in such a way that the phase is rotated 75 degrees at 836.5 MHz as the center frequency of the passband of the transmission side surface acoustic wave filter 5.

The surface acoustic wave branching filter of the present embodiment is characterized in that, in the transmission side surface acoustic wave filter 5 having a relatively low passband as described above, the parallel-arm resonator the closest to the first common terminal 4, that is, the parallel-arm resonator the closest to the antenna side is the parallel-arm resonator T1 and the capacitance of the parallel-arm resonator T1 is less than 1/10 of the capacitance of the other parallel-arm resonators T4 and T7, different from the parallel-arm resonator T1, sandwiched between the series-arm resonators. In such a way, leakage of a signal to the reception side surface acoustic wave filter 6 from the transmission side surface acoustic wave filter 5 can be suppressed. That is, isolation characteristics can be improved. This is described with reference to Figs. 4 to 9.

In the present embodiment, the number of pairs of electrode fingers, the cross width of electrode fingers, the wavelength, and the number of electrode fingers of reflectors of each resonator used in

the transmission side surface acoustic wave filter 5 and the reception side surface acoustic wave filter 6 are as shown in Table 1 and Table 2.

Table 1

No. of resonator	Number of pairs	Cross width	Wavelength	Number of electrode fingers of reflector
T1	50	20	4.892	15
T2	164	110	4.656	15
T3	164	110	4.667	15
T4	80	125	4.892	15
T5	112	102	4.662	15
T6	112	102	4.662	15
T7	80	125	4.892	15
T8	112	200	4.673	15
T9	163	135	4.694	15

Table 2

No. of resonator	Number of pairs	Cross width	Wavelength	Number of electrode fingers of reflector
R1	125	64	4.575	15
R2	115	126	4.368	15
R3	115	39.4	4.368	15
R4	125	203.5	4.569	15
R5	115	39.4	4.368	15
R6	115	126	4.368	15
R7	112	72	4.575	15

Furthermore, since the result shown in Figs. 4 to 9 was obtained by properly modifying the structure (construction) of the resonators used in the surface acoustic wave branching filter of the above embodiment, and the case in which the capacitance ratio is 1/10 corresponds to the present embodiment.

Fig. 4 shows the change of isolation when the capacitance ratio between the parallel-arm resonator T1 and the parallel-arm resonators T4 and T7 is changed. Fig. 5 shows isolation characteristics when the parallel-arm resonator T1 is not connected and when the above capacitance ratio of the parallel-arm resonator T1 is 1/20 and 1/10 (representing the present embodiment). Furthermore, Fig. 6 shows the

relation between the capacitance ratio and the insertion loss of the transmission side surface acoustic wave filter. Fig. 7 shows insertion loss characteristics of each transmission side surface acoustic wave filter when the parallel-arm resonator T1 is not connected and when the capacitance ratio of the parallel-arm resonator T1 is 1/20 and 1/10 in the same way as in Fig. 5.

Furthermore, Fig. 8 shows the insertion loss of a reception side surface elastic wave filter to the capacitance ratio. Fig. 9 shows the insertion loss of each reception side surface acoustic wave filter in the case when the parallel-arm resonator T1 is not connected and when the capacitance ratio of the parallel-arm resonator T1 is 1/20 and 1/10. Moreover, the inner attenuation value to frequency characteristics shown in Fig. 9 are magnified in accordance with the right-hand scale of the perpendicular axis.

Moreover, in Fig. 7, the inner attenuation value to frequency characteristics are magnified in accordance with the right-hand scale of the vertical axis.

As is clearly understood from Fig. 5, leakage from the transmission side surface acoustic wave filter 5 to the reception side surface acoustic wave filter 6 is suppressed and isolation characteristics can be improved by having the parallel-arm resonator T1 provided when compared with the case where the parallel-arm resonator T1 is not provided, that is, the case where the resonator the closest to the first common terminal 1 is the series-arm resonator T2 in the transmission side surface acoustic wave filter 5. Furthermore, as clearly understood from Fig. 4, isolation characteristics can be improved particularly in the vicinity where the capacitance ratio is 1/10. That is, when a resonator of the transmission side surface acoustic wave filter 5 which is the closest to the first common terminal 4 on the antenna side is the parallel-arm resonator T1, it is understood that isolation characteristics can be

improved in comparison with the case where the resonator which is the closest to the common terminal 4 is a series-arm resonator.

Accordingly, in the surface acoustic wave filter circuit of a ladder-type circuit structure, up to now, although it is stated that the most appropriate capacitance ratio is 1/2 in Patent Document 3, when the change of isolation characteristics in Fig. 4 is considered, it is understood that the capacitance ratio of less than 1/2 is desirable in the surface acoustic wave branching filter having the first and second surface acoustic wave filters connected therein. That is, it is understood that, by making the capacitance ratio less than 1/2, a surface acoustic wave branching filter in which isolation characteristics are improved can be provided in comparison with the case where a surface acoustic wave filter having a capacitance ratio of 1/2 is used.

On the other hand, as is understood from Fig. 4, when the capacitance ratio is less than 1/40 or exceeds 1/5, isolation characteristics become equivalent to the case where the parallel-arm resonator is not connected (capacitance ratio = 0). Accordingly, it is desirable to make the capacitance ratio in the range of 1/40 or higher and 1/5 or lower.

As is clearly understood from Figs. 5, 6, 8, and 9, there is a tendency that the higher the capacitance ratio becomes, the larger the loss of the transmission side surface acoustic wave filter 5 and the loss of the reception side surface acoustic wave filter 6 become. However, as is clearly understood from Figs. 6 to 9, when the capacitance ratio is 1/5 or less, the loss in the transmission side surface acoustic wave filter 5 and the reception side surface acoustic wave filter 6 is relatively small.

Accordingly, more preferably, when the capacitance ratio is in the range of 1/40 to 1/5, deterioration of the insertion loss is suppressed and simultaneously isolation characteristics can be

improved.

Furthermore, in the present embodiment, the grounding side terminal of the parallel-arm resonator T1 which is the closest to the first common terminal 4 and the grounding side terminal of the other parallel-arm resonators T4 and T7 included in the surface acoustic wave filter chip 5A are commonly connected to the second common terminal 7. Then, the second common terminal 7 is connected to the ground potential through the inductance element Z. Accordingly, since the inductance element Z is added at the portion where the parallel-arm resonator T1 is connected to the other parallel-arm resonators T4 and T7 through the common terminal 7, even if the capacitance of the parallel-arm resonator T1 is small, isolation characteristics can be effectively improved.

Furthermore, preferably, the resonance frequency of the parallel-arm resonator T1 is made the same as the resonance frequency of the other parallel-arm resonators T4 and T7. In that case, no additional insertion loss due to the difference of resonance characteristics is caused and, as a result, isolation characteristics can be improved as described above.

Moreover, since the phase adjustment element 9 is connected to the reception side surface acoustic wave filter 6, the DPX coupling loss on the side of the common terminal 4 on the antenna side can be reduced.

In the present embodiment, preferably, the amount of phase rotation by the phase adjustment element 9 of the reception side surface acoustic wave filter 6 is made less than 90 degrees from the center frequency of the passband of the reception side surface acoustic wave filter. In this case, since the amount of phase rotation can be made smaller, the phase adjustment element can be reduced in size and, as a result, the surface acoustic wave branching filter 1 can be downsized.

In particular, when the amount of phase rotation is made less than 90 degrees, in a stage before the transmission side surface acoustic wave filter 5 and the reception side surface acoustic wave filter 6 are coupled on the antenna side, the phase is made inductive in the passband of the reception side surface acoustic wave filter 6 and the phase is made capacitive in the passband of the transmission side surface acoustic wave filter 5. Thus, the impedance matching can be realized. In particular, in the construction in which the resonator the closest to the common terminal 4 on the antenna side is a series-arm resonator, when the passband of the transmission side surface acoustic wave filter 5 is made capacitive, as shown in Fig. 11, the larger the capacitance, the larger the movement on the Smith chart and the reflection increases. Accordingly, the loss at the DPX coupling increases.

On the contrary, in the case in which, as in the present embodiment, a resonator the closest to the common terminal 4 on the antenna side is the parallel-arm resonator T1, when the passband of the transmission side surface acoustic wave filter is made capacitive by addition of the parallel-arm resonator T1, since the movement as shown in Fig. 10 is performed, the reflection decreases and, as a result, deterioration of characteristics at the DPX coupling can be suppressed.